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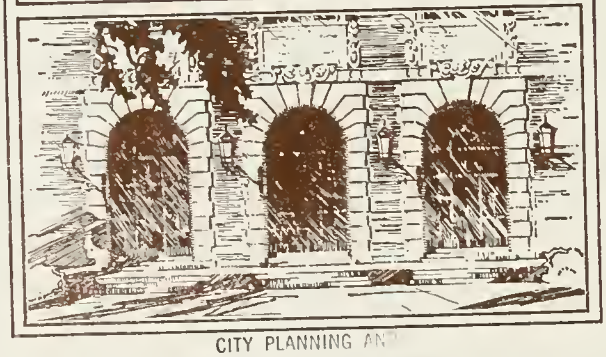

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OCCUPANCE AND USE OF UNDERGROUND MINED OUT SPACE IN URBAN AREAS: An Annotated Bibliography

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OCCUPANCE AND USE OF UNDERGROUND MINED OUT SPACE IN URBAN AREAS:

AN ANNOTATED BIBLIOGRAPHY

by

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INTRODUCTION

Secondary use of mined-out space in underground limestone quarries is exemplified extensively in the Kansas City area where abandoned quarry sites are being renovated into warehouses, factories, and offices. Mining techniques, ceiling heights, and pillar distribution are being altered as planning for the secondary use of mined-out space is combined with the quarrying process. Even the historic urban-quarry land use conflict invites a reappraisal in that this development provides a potential resolution of the problem. Mutual subsidization by dual rock and space interest is changing the economics of rock production.

A national survey conducted by the author early in 1971 revealed that Missouri led the contiguous United States in the secondary use of space mined out of a limestone matrix with the greatest concentration occurring in the Kansas City area.

These findings inspired further research to define those factors which are ubiquitous to subsurface development, evaluate the social and economic impact of this phenomenon, and project its relevance by suggesting generalizations applicable to similar situations.

Social and Economic Impact

The economic impact stemming from revitalization of once dormant abandoned quarries is felt in Kansas City as some 1700 employees earn more than $13,000,000 annually some 50-100 feet below ground in rooms mined out of limestone. Property values are increased both adjacent to and including the converted mine sites.

The secondary use of an otherwise abandoned mine is a dynamic factor in the neighborhood. The use of the subsurface is often accompanied by a plan of total development which includes intensive use of the surface. A more permanent geographic relationship with the community replaces the temporary perspective usually associated with the quarry operation. The economic input from secondary use commonly exceeds that of its rock production.

Land use problems of an urban-quarry nature are being resolved as quarry operators sit with developers and plan the future of their mining site as a permanent industrial park with storage facilities, factories, and offices below ground, and regular use of the surface for stores, parks, and common urban development. Long range plans are laid for the use of the mined-out space which is more valuable than the once-over exploitation of the rock. The neighborhood accepts the planned secondary use of a mine with far greater approval than the spectre of fenced wasteland often left by mining and later engulfed in the path of urban growth. The continued use of the land assures tax potential and economic support for the city.

Major secondary uses are warehousing, factories, and offices in that order. One-seventh of Kansas City's warehousing is now underground. The Department of Agriculture reports that Kansas City has 34,473,000 cubic feet capacity for frozen food storage about one-tenth of the total such capacity of the entire nation most of which is underground. A lawnmower parts factory makes use of the unlimited carrying capacity of the floors for its heavy industrial tooling and milling, while a sailboat factory utilizes the easily controlled humidity for setting its lacquers and glues. Printing shops take advantage of the controlled humidity for maintaining quality control.

Currently there are 28 subsurface sites in varying stages of development in the Kansas City area, encompassing nearly 70 million square feet of space, 30-200 feet below the surface, with floors that dip less than ten feet per mile.

Long term occupance of the subsurface for a variety of functions has clearly demonstrated several distinct advantages in use of the underground environment, for example:

1) mined-out space can be purchased or leased at a fraction of the cost for comparable surface facilities;
2) roof and foundation problems are reduced or eliminated;
3) floors are capable of supporting unlimited installations or storage weight;
4) complete noise and vibration control is possible;

5) the areas are fireproof and command the lowest insurance rates in the area;
6) greatly reduced costs in heating, air conditioning, or freezing as the consequence of insulation from the rock, and
7) vastly improved security for equipment, records, and personal protection.

Salient Features

What accounts for this development in the Kansas City area? The answer is related to the occurrence of a limestone bed named the Bethany Falls by geologists, which averages 20-25 feet thick and extends throughout the entire Kansas City area. Many square miles of this bed are in the subsurface, although reasonably close to the surface. In many places the bed outcrops at the surface, especially in bluffs along valley slopes. Several factors combine to make the Bethany Falls limestone ideal as a site for subsurface exploitation in both primary (mining) and secondary (conversion) development. They are:

1) Because this bed has been and is now the principal quarry rock throughout the history of Kansas City, there are many extensive subsurface openings left as an aftermath of quarry operations;
2) Many underground openings, oriented to bluffs, are in localities with natural accessibility to transportation lines on the valley floors;

3) This layer is a massive, thick limestone, overlain and underlain by impermeable shales which inhibit water seepage into the Bethany Falls, and

4) The beds are nearly horizontal, which provides better than usual opportunities for extensive expansion into the subsurface.

The Future

Although Kansas City has ideal geologic and geographic conditions for seemingly limitless subsurface development and exploitation, it is true, of course, that many other areas of the United States and the world must have somewhat comparable conditions for similar developments elsewhere. It is hoped that the references to Kansas City uses may be viewed in light of their potential for universal application where the physiography permits.

The energy conservation factor achieved through use of the insular qualities of subsurface rock ceilings and walls may predicate extensive use of the subsurface for a variety of purposes. The future in this respect holds opportunities for human habitation as well as commercial uses.

Urban Geologic Relationships

A city is much more than a surficial adjunct superimposed upon the topography of an area. Its development and growth are deeply rooted in the resources, benefits and problems of its underlying geology. The environmental geologist must address himself to more than the quality of a particular resource. He must comprehensively relate resource extraction and processing with the urban emphasis of optimal use which favors long term usage of land over one time economic ventures. Limestone quarrying, closely allied with the growth of many cities, has commonly left a series of scarred landscapes in the path of the burgeoning metropolis. These abandoned quarry sites are barriers to orderly city growth and fail to serve the people as useful and taxable land. Where quarries are functional, supplying the city with needed growth, minerals, problems of blasting damage, noise, and dust exists. Technology faces the challenge of making mineral production and processing good neighbors to the urban market they serve. Continued growth of cities may require more efficient use of space below as well as above the surface optimizing land usage so that long term economic benefits may be reflected in improved mining methods.

Nature and Structure of the Bibliography

Most items in this bibliography refer to underground development and occupance of space in the Greater Kansas City area. It is believed that such information obtained from the Kansas City attention to this endeavor may be applicable elsewhere where comparable physiographic and geologic circumstances permit.

The term underground as used in the following references applies to geologically separated levels and not to basement type developments. The matrix studied at Kansas City is entirely limestone. The term cave is a misnomer. There are no caves in the Kansas City area. These are all mined out rooms leaving support pillars.

The uniqueness and receny of underground space usage, on the scale perceived in the years ahead, has not as yet led to an extensive list of conventional reference materials. To assemble the reference items it has been necessary to make use of newspaper reports, brochures, and unpublished papers. All references are on file in the Department of Geosciences, University of Missouri-Kansas City, and may be obtained on request should local libraries and other sources be exhausted. A few references are not directly related to underground use but are included as sources for stimulating thought.

For ease of reference the items in this bibliography have been grouped into the following sections:

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I. General Uses of Underground Space.............. 8
II. Underground Uses Relating to Security Needs....23
III. Employee Attitudes...........................26
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I. GENERAL USES OF UNDERGROUND SPACE

Particular reasons for locating underground are frequently cited in these references:

A New Concept in Space...Underground. A pamphlet by Underground Storage, Inc., 7800 East Birmingham Road, Kansas City North, Missouri.

This brochure treats the uniqueness of underground storage and the way by which this can mean lower costs to the user. Some 200 acres of underground storage and manufacturing area is quoted at 30-40% less than similar surface space. Even climates can be maintained whether for storage of sugar, frozen foods, curing of tiles, manufacturing or offices.

A Unique Subterranean Facility. The Ozark Terminal, Inc., P. O. Box 471, Neosho, Missouri, 64850.

Color pamphlet illustrating the Ozark Terminal Underground Warehouse in Neosho, Missouri. Map included.

"Aero Drapery Company into a Cave." Kansas City Star, May 14, 1967.

Customers are often surprised when the address takes them to an elevator which lowers them 140' to a cheerful display of fabrics where drapes are purchased in an underground display room and manufactured in the controlled climate of large underground rooms.

"Air Skipper "Moonlights" As Cavern Boatbuilder. International Trail, Volume 35, No. 1, 1965.

Advance Sailboat Corporation with 19 employees, uses an abandoned limestone mine in the manufacturing of boats. The controlled climate of the underground rooms with dependable constant humidity allows perfection in the setting of glues and drying of resin.

Becker, H. G., Jr. A Favorable Balance of Trade, (handling and shipping), FTZ & PDM, March 1973.

Discussion of the trade zone concept and the concept of physical distribution management as concerned with underground development. Color pamphlet. Excellent pictures show both the exterior and interior of the subsurface developments.

Callahan, S. J. Development of Limestone Mines Into Underground Warehouses, Conference Reprint 257, American Society of Civil Engineers, 1965.

Discussion of quarry operations, geological and engineering aspects, transportation, construction, and utilities in the development of underground warehousing and lists facilities in K.C. area. He concludes this use of underground space will greatly increase, and predicts that manufacturing use will also increase.

"Campers Safe In Off-Season "Vault"." Kansas City Star, November 21, 1973.

Ray Shields and Bob Means initiated the conversion of two abandoned mine sites into storage for boats and trailers. Some 2,000 vehicles are currently being stored where they are protected from weather and vandals. Storage space cost ranges from $5.00 a month upward depending on size of craft.

Carthage Marble Corp. "Use of Underground Space," from Missouri Mineral Industry News, Volume 9, No. 1, January 1969, p. 1.

Brief article concerning the Carthage Marble Company's underground facilities near Carthage, Missouri.

Cham-Pagne-Underground and Surface Industrial Park. A pamphlet by Cham-Pagne Underground and Surface Industrial Park, 16400 East Truman Road, Independence, Missouri.

This booklet describes the permanent and in transit storage facilities available showing warehouses areas and offices. This development also includes a large lawnmower parts manufacturing company which makes use of the natural floor strength for their large and heavy machinery.

Chappell, Charles S. "(For Kansas City) Foreign Trade Zone Approved," The Journal of Commerce and Commercial, 99 Wall Street, New York, New York, March 27, 1973 issue.

Underground areas become Foreign Trade Zone's in Kansas City.

Christian Science Monitor. "Kansas City Firms Go Underground," September 21, 1961.

An account of some firms which have selected underground locations citing low rent, controlled temperature and humidity as a few of the factors. Low rent is partially possible due to low cost of installation and maintenance of heating and air conditioning equipment. The equivalent of heating for a 20 room apartment, or 50 tons of air conditioning dehumidifies 140,000 square feet is given as an example of efficiency.

"Claims Asthma Cure Found in Ancient Salt Mine." Kansas City Times, January 20, 1972.

People claim relief from asthma after several days in salt mine in Poland. Sanatorium is being built in the mine.

"Cleveland Exhibition Hall Goes Underground." Engineering News Record, Volume 174, No. 13, April 8, 1965, pp. 87-88.

Cleveland has added 208,000 square feet to its convention center by building an exhibition hall under the old convention center structure. Article gives construction details. The exhibition hall was built underground to preserve the beauty of a mall, which covers two blocks in the downtown area. The mall was excavated to permit construction underground and then reconstructed after completion of the project. In the case of using a mined area the surface beauty can be maintained.

Coe, Vernon. "Railroads Serve the Nation from Kansas City," Kansas Citian, September 1970, pp. 32-33.

Optomistic report on the present and future of K.C.'s railroad industry. The railroad is an important adjunct to the development of underground space in that currently warehousing makes up 85% of underground space use.

Collins, A. C., Jr. "Missouri River Provides Waterway," Kansas Citian, September 1970, pp. 23-24.

Report on the revival of the Missouri River as an important inland waterway and descriptions of different types of barges. Nearness to the economical water transfer of bulk materials is viewed as an asset by underground space developers.

Congressional Record. "Space Age Cave Dweller," Volume 109, No. 109, July 18, 1963.

This appendix quotes A. N. Brunson as he recounts his development of the underground facility in the Kansas City area and is introduced as an example of American ingenuity to the nation.

Dispatch. "Business Thrives Underground in Clay County," January 27, 1972.

An account of the large underground facilities of the Great Midwest Corporation where 25 miles of 12 foot high products are stored from such firms as Quaker Oats, General Foods, and H. J. Heinz. Utility costs are a mere $10,000 annual electric bill mainly lights and refrigeration, since heating is unnecessary and water is supplied from above ground springs. The total space now in use is 1.4 million square feet including 250,000 square feet kept at 0-10° below and 30,000 square feet kept at 45-50° with the rest at about 60-65°.

"Double Duty from Hidden Assets." Fortune, Volume 73, January 1966, pp. 175-176.

Inland Underground, a Kansas City limestone mining company, rents out underground mined out space for storage, industry, etc. The space is prepared by Inland at a cost of about $3 per square foot and rented for no more than $2.50 per square foot annually. This is very profitable in that income is derived from both the rock and the space from which the rock is removed.

Earney, Fillmore C. "Mushrooms and Mines: A Study in Horticulture," Journal of Geography, Volume LXVII, No. 1, January 1968, pp. 42-48.

Discussion of the Butler County Mushroom Farm in Pennsylvania, which operates in an abandoned limestone mine.

Economist. "Japan: Underground Movement," Volume 221, December 24, 1966, p. 1323

Brief article on underground developments in Tokyo, which has difficult traffic and air pollution problems, as well as the highest land prices in the world. There are 25 "chikagai" (subterranean towns) in Japan and more are planned. These, however, are not geologically separated from the surface as in the use of mined out areas.

Extensive Underground Area Available. By Carthage Marble Corporation, P. O. Box 718, Carthage, Missouri, 64836, 1970.

Booklet description of 13 acre underground area of mined-out limestone quarry, with map; showing mileage to cities, railways, and highways. Also advantages of underground facilities in Carthage as well as in the rest of Missouri are discussed.

"Foreign Trade Movement Here Intensified." Kansas City Star, January 20, n.d., p. 2E.

Greater K.C. Foreign Trade Zone with most of its operations in underground mined out space is operating at an economic savings because of the insular quality of the limestone rock ceilings and walls.

Foreign Trade Zone and Sub-zones in Greater Kansas City. Greater K.C. Foreign Trade Zone, Inc., P. O. Box 13244, Kansas City, Missouri, 64199, 1972.

Color pamphlet explaining the concept of the international trade zone and the unique advantages of the zone concept and a listing of its Board of Directors.

"Foreign Trade Zone Sites." Kansas City Star, April 1, 1973.

A photograph showing the Great Midwest Corporation facility which will initially have outlay of 315,000 square feet for a Foreign Trade Zone. Ultimately expansion of the same site can reach over 40 million square feet.

"Foreign Trade Zone Status to Kansas City." Kansas City Times, March 24, 1973, p. 1.

Foreign Trade Zone Status is conferred on Kansas City, Missouri which makes use of underground space operated by Great Midwest Corporation at 7800 East Birmingham Road. A carpet importer will be one of the initial tenants.

Gagnier, Richard. "Advantages for Below-Ground Businesses," U-News, (University of Missouri-Kansas City Student News), February 15, 1973, p. 6.

News report of a tour of underground facilities by UMKC faculty and administration including Paddocks studios, located underground for the reason of quietness since rock walls insulated the recording chambers from surface noise.

Glenn, William. "K.C. has Motor Freight Growth," Kansas Citian, September 1970, pp. 24-26.

Report on the growth of K.C.'s trucking industry part of which relates to the extensive warehousing industry in the Kansas City area. One seventh of the warehousing in Kansas City area is located underground.

"Going Underground." Progressive Architecture, Volume 48, April 1967, p. 139.

Collection of small articles about underground development:

History is With Us
Norad's Command Post
Sweden Digs Down
Big Corporations Take Cover
Schoolrooms Go Under
A Sanctuary from the World
Texan History Within Earthworks
Nuclear Shielding for Oursiders
Johnson Underground
Putting Books Below Ground
Parisian Theatre
Commerce and Industry Dig Down
Preservation of Landscape
Vanishing Eyesores

Hadley, Richard D. "College Ponders Opening Mine," The Kansas City Star, Wednesday, October 24, 1973, p. 4A.

Park College is considering opening a limestone mine as a source of income under the campus with the intention of using the mined out space for a variety of campus functions.

Hamilton, L. D. "A City Under the Ice Cap," American City, July 1963, pp. 100-102.

Report on the U. S. Army's Camp Century, an underground community 800 miles from the North Pole built in 1960 to determine what is needed for the function of a self-sufficient community under artic conditions. The living and research tunnels are 50 feet underground, connected by 27 "streets." Camp Century has an atomic power plant and modern sewage and water systems. Supply is the most difficult problem faced by this community but the Army is working to overcome this and prove the feasibility of settlement and exploitation of resources in artic areas.

Hammer, Charles. "Bold Concept for Underground Freeway," Kansas City Star, December 1, 1968.

A proposal for the development of an underground system of streets utilizing the Bethany Falls Limestone Member from which the rock would be stockpiled and marketed offsetting part of the construction cost. Advantages would be less disturbance of established neighborhoods, less loss of taxable income from surface property, less additional cost for right of way by optimal use of space beneath existing streets and minimal weather hazards.

Hockenberry, S. H. "Can Industry and Nature Coexist?," Iron Age, Volume 203, June 1969, p. 61.

Brief article reporting on the combined industry-scientific Environmental Science Center in New Jersey to be constructed by 1971. The building will be half underground.

"Huge Trade Zone Expansions Here." Kansas City Times, December 22, 1973, p. 1.

Inland storage distribution center was approved as Foreign Trade Zone area with 405,000 square feet and Great Midwest Corporation was increased by 2½ million square feet. These underground areas bring a total of 3,220,000 square feet of mined area into secondary utilization as a Foreign Trade Zone.

"Industry Goes Underground." Mechanical Engineering, August 1961.

Brunson cites his underground construction cost for creating factory space as being $6 per square feet as compared to $12 if built on the surface. Insurance cost was reduced from $2.85 per hundred to 20¢ and the constant temperature of 54° required very little air conditioning.

"Industry Tries Living in Caves." Business Week, No. 1655, 1961, pp. 166-170.

Kansas City has taken the lead in the U.S. in utilizing underground space for industrial and manufacturing purpose. Article discusses benefits of underground location, such as lowered costs, convenient temperature and humidity control, lack of vibration, and lessened danger of fire.

Inland Underground Facilities. A booklet by Inland Underground Facilities, 6500 Inland Drive, Kansas City, Kansas.

This booklet with color photographs describes the storage and refrigeration accommodations of the Inland Underground Facilities, a Division of Beatrice Foods. It shows both rail and truck docks as well as computer equipment.

"Instrument Company Developed Mine for Factory Site." Pit and Quarry, January 1963.

Describes use of underground space by Brunson Instrument Company of Kansas City, Missouri. Location is free from vibration, dust, noise, and offers security. Only 5 miles from downtown Kansas City in an old limestone mine. Article points out Kansas City area was logical site for a meeting of Corporate Officers Symposium on underground facilities as it ranks only next to Sweden in underground facility potential.

Jackson County Sentinel. "Building Pace Quickens in Blue Springs," November 30, 1972.

An underground distribution center has been proposed in Blue Springs a suburban city some 20 miles from Kansas City.

Kansas City Chamber of Commerce. "Guide to Industrial Sites of Metropolitan Kansas City,"1970.

A booklet giving exact descriptions of available industrial sites in Kansas City including underground facilities. Color photos.

Kansas City Star. May 21, 1972.

Banquet held in underground storage facility honoring 200 Japanese industrialists who were here for the purpose of viewing underground storage facilities and its potential for foreign trade development.

"Kansas City Warehouse Statistics Impressive." Kansas Citian, September 1970, p. 34.

Brief report on K.C.'s warehousing industry.

Kiewit, Fred. "Area Agribusiness Needs 'Hard Sell'," The Kansas City Star, October 8, 1972, p. 6D.

Foreign Trade Zone is designated by trade experts as a major stimulus to Missouri's agricultural exports. The underground storage facility, an abandoned limestone mine, has been converted to storage use for this purpose.

MacCurdy, George Grant. "American Caves and Cave Dwellers," American Journal of Archaeology, Volume XLI, No. 3, July-September 1937, pp. 383-387.

The author summarizes archaeological knowledge of the earliest known American Indian cultures, (Folsom, Yuma and Basket-Maker), which date from the late paleeolithic. He mentions the important finds, in caves, valley deposits and rock shelters, stressing the importance of cave findings.

"Maginot: The Line That Failed." Newsweek, March 1969.

The famous Maginot defense line, made up of concrete pillboxes and bunkers has been turned into barns, underground store rooms, and temporary living quarters. The average bunker sells for $1,000.

Mann, Colin. "Australians Beat Desert Drought," K. C. Star, August 23, 1971.

The town of Coober Pedy in South Australia has most of its 3,000 population living underground in 70° homes while the surface reaches as high as 122°. Sandstone is the matrix for this development and the water is supplied from an additional depth of 300 feet where natural reservoirs are tapped. Picture of solar still for water purification is shown. Australian Information Service Photo.

Material Handling Engineer. "New Breakthrough in Underground Warehousing," November 1960, pp. 72-75.

A new full-scale underground warehouse that will cause a breakthrough by directing the attention of material handling men underground. Discusses advantages and problems.

McCandless, Kenneth. "Geotecture," Industrial Design Magazine, April 1973, pp. 52-53.

Introduction of the concept of geotecture. Stresses the specific advantages of subterranean development as well as its technical feasibility. Technical, economic and climatic questions are discussed.

Missouri. Commerce and Industrial Development Division. Proceedings of the Corporate Officers Symposium on Underground Facilities, June 25-26, 1962.

Proceedings of a symposium held in the underground facilities of Brunsons Kansas City plant. The artificially climated area, created inexpensively in the underground, was cited as often desirable. The case of the science laboratory at the Menorah Medical Center which though built above ground was made windowless, was cited as an example. Industry was encouraged to explore possibilities of underground usage.

Missouri Division of Commerce and Industrial Development. Available Buildings in Missouri, March 1970.

Listing of buildings by size as well as location. Among which are several underground areas.

Missouri Mineral News. Volume 13, No. 11, November 1973, p. 192.

An article on deep shaft mining and crushing of stone underground in the Kansas City area. This refers to a deeper limestone than the layer normally used for warehousing in Kansas City. What the future holds for the space developed at this depth is uncertain.

"Missouri's Inner Space." The Harbinger, February 1971, pp. 4-8.

Discussion of the underground industrial facilities and industrial space available in Missouri. Notes examples of areas already in use as well as projected sites. Illustrated in color with particular emphasis on the Brunson plant in Kansas City.

"Mother Nature and Modern Science Supply Refrigeration." Frozen Food Age, August 1971.

Describes a subterranean warehouse and total distribution center making use of the insular quality of the rock as an economic asset in maintaining freezer space economically. This mine last used in 1957 is now a storage facility with railroad lines and trucks serving the nation.

"New Industry Is Going Underground." K. C. Star, January 28, 1970.

An account of the newly formed Overland Distribution Centers, Inc., as it began to develop more than 800,000 square feet of mined out area at a project cost of 5 million dollars. The article lists Dr. Arthur B. Rhodes as President and Grady Truitt as Secretary of the firm with operation to begin in August. Some 185 acres of surface area and 3,300,000 square of subsurface comprises the total extent of the site.

Oler, Frank. April 13, 1973.

Letter from Mr. Oler regarding the Zero Mountain Project of Fayetteville, Arkansas. Underground cold storage facilities operate in a former limestone quarry. This site is used mainly by the poultry industry in freezing, canning and storage of poultry products.

Overland Distribution Center, Inc. A pamphlet by Overland Distribution Centers, Inc., 16500 East Truman Road, Independence, Missouri.

A description of underground storage and distribution facilities now operating in over a million square feet of an abandoned mine. Pictures include truck and rail docks, offices and computer facilities as well as a map of the freezer and storage rooms.

Peck, Roy L. "Medusa's Underground Technical Center," Pit and Quarry, November 1966.

An effective utilization of an abandoned underground working in Medusa-Portland Cement's new technical center in Wampum, Pennsylvania. It is an abandoned limestone mine with almost constant temperature. Medusa only had to put in heating and dehumidifying equipment. The report states that solid limestone when initially cleaned does not disintegrate or produce further dust.

Quick Frozen Foods. E. W. Williams Pub. Inc., Vol. 33, No. 1, August 1970. (205 East 42nd., New York, New York).

Cites the importance of frozen foods which make up 10% of retail sales and 15% of profits. Most of the nation's 60,000,000 homemakers are under 30 and depend extensively on foods that are preserved by freezing.

Quincy Space Center, 8th and Front Street, Box 1084, Quincy, Illinois, 62301, n.d.

Illustrated color brochure of the Quincy Space Center. Road mileage to various cities as well as other advantages of this underground structure are discussed.

Roberts, Joe. "Great Midwest River Village Plan a Foreign Touch," K. C. Star, October 14, 1973.

Eighteen stories below the surface a series of reproduced villages of North and South America and the Far East are planned for Fall of 1974. This will use extensive mined rooms to create an impressive trade mart as part of the International Free Trade Zone concept. Potential buyers may shop among the items on display in ideal climatic conditions.

Roberts, Joe. "Trade Zone Facility Concept Unique," The Kansas City Star, April 8, 1973, p. 1E.

Proposed Trade Zone Facility makes extensive use of underground space, which is an innovative project by Great Midwest Corporation and is designed to have office facilities on the surface with exhibit space and warehousing underground.

Roberts, Joe. "Cave Storage Upgrading Continues," K.C. Star, January 10, 1971.

Mining and secondary use of the underground are occurring simultaneously at the Great Midwest Corporation in Kansas City. Mining is proceeding at some 700,000 square feet annually with the rock being used for aggregate and concrete construction. 1,200,000 square feet has just been let to Space Center, Inc., one of the largest public warehouse operators in the nation.

"Rock-Bottom Refrigeration Costs Increase Frozen Food Profits." Dun's Review and Modern Industry, March, August 1963.

Freon advertisement citing its use in a 1000 horsepower centrifugal compressor to handle 18-3/4 million cubic feet of refrigerated warehouse space in the Inland Underground Facilities, Inc., in Greater Kansas City.

Russell, Dick. "K.C. Cave Men," Topeka Capital-Journal, February 18, 1973.

An account of how Amber Brunson developed his underground factory where optical instruments for the Apollo 11 and 12 moon shots were made. An account of how vibrations from passing traffic hindered his high precision production in a surface location and how he moved underground and escaped such problems.

Sanoff, H. "Seven Acres of Underground Shelter," American Institute of Architects Journal, Volume XLVII, No. 2, February 1967, pp. 66-68.

Between 1908 and 1946 Baldasare Forestiere, an Italian tunneler, created an underground home under the desert. The labyrinth has 65 rooms, gardens, and grottos, all illuminated by natural sunlight through skylights. The reason he built it is not known.

Stauffer, Truman P., Sr. "Kansas City: Center for Secondary Use of Mined Out-Space," abstract published as preprint No. 73-163, Society of Mining Engineers of A.I.M.E., New York, 1973.

This article cites the leadership of the Kansas City area where over 1700 persons work 50-200' below the surface daily in a variety of establishments ranging from light and heavy manufacturing to warehousing and offices.

Stauffer, Truman P. Kansas City's Future is Tied to Its Unique Subsurface Laboratory, abstract published in abstracts with Programs Volume 5, No. 7, 1973, pp. 919-920, of the 85th Annual Meeting of the Geological Society of America Meeting in Dallas.

The Kansas City area is viewed as a laboratory in which private industry has experimented and developed a variety of secondary uses of mined-out limestone rooms. Factories, offices, and warehousing is developed in an organized sense making use of trucks and rail transportation to subsurface sites.

Stauffer, Truman P., Sr. "Occupance and Use of Underground Space in the Greater Kansas City Area," Dissertation Abstracts International, Volume XXXIV, No. 1, 1973.

An abstract of a Ph.D. Dissertation which is on file in the University of Nebraska, Lincoln Library.

Stauffer, Truman P., Sr. "Use of Mined Out Space in Greater Kansas City," International Geography, Volume 1, pp. 672-673, 1972, published by Toronto Press for the 22nd International Geographical Congress.

This article cites the extent of the secondary use and conservation of mined out waste land which has been converted to an income producing, taxable, and desirable land use within the urbanized area of Greater Kansas City.

Steel. "How to Bury Your Business and Save Money: Missouri Promotes Use of Underground Space," Volume 151, p. 68, November 12, 1962.

Missouri has 30 million square feet of mined out limestone caves available for industrial development; more than 1/2 of these are in or near Kansas City. The article gives examples of business with underground facilities and notes the cost savings that often result. It states that Missouri Resources and Development Commission has prepared a 36-page booklet listing space in 19 major locations.

The Cavern Sound. A pamphlet by Cavern Studios, 16400 East Truman Road, Independence, Missouri.

Describes the noisefree, vibrationless, climate controlled features of an underground studio for making broadcasts of recordings.

"Trade Zone Buoys Leaders." Kansas City Star, March 24, 1973, p. 1.

Business leaders see a bright future for a trade zone in K.C. using an underground area.

"Trade Zone Lease." Kansas City Star, December 27, 1973, p. 4.

A Helsinki corporation, one of the largest diversified manufacturers from Finland, was one of the first foreign firms to lease space in the underground Foreign Trade Zone site of Great Midwest, a developer in Kansas City.

"Trade Zone Spread Inland." New York Times, Section 3, October 8, 1972.

The Foreign Trade Zone application was approved for Kansas City. The article includes an artist's rendering of Great Midwest's proposed foreign free-trade zone showing display, office and storage areas built in underground caverns left by limestone mines. Elevators would connect these areas with above-ground facilities.

"Underground Home of the Future Debuts at the Fair." Electrical World, Volume 161, No. 15, April 20, 1964, p. 165.

Report on a model underground home at the New York World's Fair similar to one constructed by builder Jay Swayze for his family in Plainview, Texas. The home is all electric and electricity costs are about half what they would be above-ground. The article sees unlimited possibilities for underground construction. These, however, are not geologically separated from the surface as in the use of mined out rooms.

"Underground Storage." Distribution Age, Volume 65, September 1966, pp. 57-60.

Discusses advantages and disadvantages of underground storage as well as giving examples of companies that are now using this new method of storage. Illustrated.

"Unique System Installed in Downtown Industrial Park South." Kansas Citian, March 1968, p. 62.

This article describes the natural gas equipment used to generate heating, air conditioning, and electricity in the underground Downtown Industrial Park. The energy system services 1,100,000 square feet of space excavated from a massive limestone formation.

"U. S. Aviation Underground." K. C. Star, December 4, 1968.

A brief account of the underground location of a branch of FFA which utilizes the security of a subsurface location in its regular function and in training sessions.

"Warehousing on the Grow in Kansas City." Kansas Citian, May 1967, p. 62.

Because of its location and size, Kansas City is an excellent site for warehousing operations, many of which are underground in caves. The demand for warehouse space and the need for employees in this business is expected to increase.

Weber, Steve. "Bid in to Enlarge Foreign Trade Zone," The Kansas City Star, August 9, 1973, p. 13.

Great Midwest Corp. wished to enlarge its facilities, making it bigger than all FTZ's combined in U.S. This expansion is possible through the development and utilization of underground mined-out space.

Weber, Steve. "New Terminal a Spur to Trade Zone Idea," Kansas City Star, October 15, 1972, p. 8D.

The new air terminal is seen as a boost in getting Foreign Trade Zone Status conferred on Kansas City. Underground warehousing area is a major asset in the location of the trade zone in Kansas City.

Weber, Steve. "Taiwan's Changing Status May Boost Trade Here," Kansas City Star, October 8, 1972, p. 5.

Kansas City's foreign trade status is discussed with representatives of the Taiwan government. The representatives were taken on extensive tours of Kansas City's underground facilities where they could see how the existing mined-out rooms were converted to usable space at an economic savings.

Weber, Steve. "Bid in for Foreign-Trade Zone Here," Kansas City Star, June 9, 1972, p. 1, 2.

Sites under construction for Foreign Trade Zone status are discussed, including underground facilities.

Will, Barry Fegan. Of Souterrains and Submersibles, Monticello, Illinois: Council of Planning Librarians, December 1969.

An annotated bibliography on the use of subsurface citing references in which man uses the sea, gathers resources, carves crypts, and inhabits subterranean voids.

Willis, Shelby K. Transportation Underground in Kansas City, an engineering report for the Kansas Highway Engineers Annual Conference March 28, 1969 at Kansas State University and published in the Kansas Professional Engineer, Vol. XVIII, No. 8, August 1969.

The reasons for promoting the idea of underground streets are given as the rather unique geology underlying Kansas City, the economic demand for the rock removed, the proven ability to use underground space in warehousing and industry, avoidance of much surface right of way costs, preservation of neighborhoods and lower costs.

"Workers Strike at Pennsylvania Mushroom Farm." Kansas City Times, November 7, 1972.

Article about strike at Butler, Pennsylvania "Butler County Mushroom Farm, Inc.," Pennsylvania's biggest mushroom producing operation. The growing areas are underground.

II. UNDERGROUND USES RELATING TO NEED FOR SECURITY

A Modern Underground Facility. A brochure by the Wampum Mine Storage Company, P. O. Box 463, Wampum, Pennsylvania, n.d.

A well illustrated booklet showing storage area leased to U.S. Government for record storage as well as other areas in which plastic materials, wood products and movie film are stored. The area is just northeast of Pittsburgh.

American Business. "Underground Records Center Opens," Volume 30, January 1960, p. 16.

An article discussing a records center to be used by government and business. The center is located in an old salt mine near Hutchinson, Kansas. Security in the facility is a prime benefit-there is only one entrance and an armed guard is on duty.

Bayne, Charles K. "Supplemental Areas for Storage of Radioactive Wastes in Kansas," Kansas Geological Survey Special Distribution Publication No. 60, March 1972. Illustrated with maps.

Summation of data and reports on eight areas in the State of Kansas selected for study as potential underground storage sites of high-level radioactive wastes in the salt beds of the state. Conclusive report and recommendations of most suitable sites are included. Area of least suitability is listed also. Considerations of site suitability for waste storage are discussed. Considerations include safety for the area population, engineering and geologic considerations, and transportation development.

"Bringing in the Ancestors." Time, August 22, 1969, p. 52.

Underground storage of Mormon family records of Salt Lake City, Utah. Each Mormon is charged with tracing his ancestors by the religion, since they believe that any Mormon can be a "stand in" for an ancestor (or non-related person) to give that person a change for entering heaven. The records are stored at a constant temperature in tunnels inside a granite cliff.

Brunson, A. N. Statement of A. N. Brunson to Subcommittee No. 3, Brunson Instrument Company, House Armed Services Committee, U. S. House of Representatives, n.d.

This is a published version of the address before Congress in which A. N. Brunson described in detail his horizontal mining of a limestone hill for the express purpose of locating his factory underground. He recounts the qualities of noiselessness and dustlessness in a vibration free controlled climate as well as the economic advantage in cutting construction cost by sale of the removed rock. The defense against the hazards of a nuclear age in such a development was of great importance to the Armed Services Committee.

Goebel, Edwin D. Status Report of Six Month Study of the Subsurface Rocks at the Proposed Site for the National Radioactive Waste Repository at Lyons, Rice County, Kansas, Final Report: Geology and Hydrology of the proposed Lyons, Kansas Radioactive Waste Repository Site, compiled by Ernest E. Angino and William W. Hambleton. State Geological Survey of Kansas and the University of Kansas Center for Research, Inc., for the U. S. Atomic Energy Commission and Union Carbide Corporation, March 1971, pp. 38-84. Illustrated and with maps.

This article is an analysis of studies of the site of proposed surface storage in the center of an important active oil, gas, and salt-producing area of Kansas. The proposed repository site in the thick salt beds of central Kansas. It is in an area commonly referred to as part of the Continental Stable Interior. Earthquakes are infrequent in the area and of low intensity. It proposes further studies of possible thermal effects, absence of domes, and geophysical surveys measuring gravity should be made.

Goebel, Edwin D. Subsurface Analysis of Possible Alternate Sites, Geology, Hydrology, thickness and quality of salt at three alternate sites for disposal of radioactive waste in Kansas, ed. by Charles K. Bayne and Dwight Brinkley, report compiled by the State Geological Survey of Kansas and the University of Kansas, Center for Research Inc. for the U. S. Atomic Energy Commission and Union Carbide Corporation, September 1972, pp. 26-32.

Report on the distribution, thickness, and rock characteristics of Kansas bedded-salt deposits for potential underground vaults for radioactive waste. Analysis included a study of possible oil and gas penetrations as well as the strength of hydraulic heads on brine reservoirs.

Goebel, E. D., L. F. Dellwig, D. W. Brinkley, Shirley E. Paul. Salt Depth, Salt Thickness, and Salt Quality, preliminary geological investigations of supplemental radioactive waste repository areas in the State of Kansas, ed. by Ernest E. Angino, Charles K. Bayne, John Halepoaska, January 1972, pp. 56-80, maps.

A reconnaissance study for possible supplementary underground storage in Kansas underlain by salt beds at least 150 feet thick and less than 2,000 feet below the surface. Salt quality also evaluated. Eight areas were chosen for the study which met the criteria of salt thickness, overburden thickness, and generally avoid regional oil and gas trends.

How to Solve the Problems of Costly Records Storage with Maximum Protection. A pamphlet by Inland Underground Vital Records Center, 6500 Inland Drive, Kansas City, Kansas, n.d.

A description of vault services for preservation of microfilm, records and tapes provided in the underground location of Inland Underground Facilities in Greater Kansas City.

Kansas City Star. "U. S. Aviation Underground," Wednesday, December 4, 1968, p. 3D.

An account of the Federal Aviation Administration's decision to locate their office and training station some 150 feet underground in an old quarry site at 31st and Mercier.

Klass, Philip J. "Norad Operations Center," Aviation Week and Space Technology, Volume 82, Parts I and II, February 1 and 8, 1965, pp. 66-74, 65-68.

Report on the Norad Center near Colorado Springs, Colorado, which is designed to withstand a thermo-nuclear attack. Author describes security precautions of the center.

Noel, John David. "Salt Beds Favored for Wastes," Kansas City Star, October 29, 1972.

The problem of storing atomic wastes exists. Though the abandoned salt mine at Lyons, Kansas has been suggested, it is felt that storage is more than a Kansas problem - a national and international problem. Use of nuclear energy is expected to increase and salt mine storage is feasible, resulting in another use of underground storage space. Salt is relatively dry thus preventing possible seepage into underground water. Stored cannisters can be retrieved whereas they could not be easily retrieved if dumped in the ocean.

Petterson, James R. "The Magic Mountain," The Kansas City Star Magazine, July 16, 1972.

Article about the Combat Operation Center of the North American Air Defense Command. Center is located underground at Cheyenne Mt., near Colorado Springs. Located 7,000 feet up the 9565 foot mountain. Almost completly self-contained. Thirty day storage supply. Has machinery for electricity, heat, air, water and sewage.

Safe Secure Storage in Stone. Pamphlet by General Warehouse Corp., 601 North National Avenue, Springfield, Missouri, n.d.

129,000 square feet of underground warehouse and distribution center. Provides all the facilities a bank does: protection, exact accounting, immediate accessibility, top security. All at dry storage rates. Drainage system under floors.

"Specialists in Underground Storage." Fortune, Volume 58, August 1958, p. 198.

Brief article reporting on the success of Fenix and Scisson, Inc., a company in Tulsa, Oklahoma specializing in developing storage caverns underground for fuels.

III. EMPLOYEE ATTITUDES

While the author has not found easily observable differences in the hundreds of employees he has been among there are few professional studies in this area.

"Longer 'Days' Discovered During Stay Underground." Kansas City Star, November 1, 1972, p. 4C.

Michael Siffre, French Specialist in cave research reports changes in body rhythm after 205 days underground. Siffre believes individuals would fall into 48-hour cycle without 24-hour day-night cues.

MacInnis, Joseph B. "Living Under the Sea," Scientific American, CCXIV, March 1966, p. 24.

Report of a 1964 experimental saturation dive using newly developed "dwellings" and decompression equipment, and the report also mentions other research on the problems of long submersion at great depths by humans. In order to learn more about the ocean and use its resources, we need to develop the technology necessary to allow men to work on the continental shelves, which have an area of about 1,500,000 square miles. Physiological and psychological aspects of saturation diving are being studied and so far indicate that there are no barriers to prolonged human exploration of the shelf.

Wunderlich, Elizabeth. Psychology and Underground Development, U.M.K.C., prepared for Psychology 490 under Mr. Willoughby, December 1972, 13p., unpublished.

Study of effects of underground environment using psychological techniques and questionnaire. There is a great need for further inquiry because of an anticipated expansion of underground space use. Author summarizes research in this area.

IV. GEOLOGY OF THE KANSAS CITY AREA

Lithologic comparisons to other areas may be made from these references.

Buckley, E. R. The Quarrying Industry of Missouri, Director, Missouri Bureau of Geology and Mines, Volume 2, 2nd series, n.d.

Detailed maps and information on numerous quarries in the State of Missouri.

Directory-Missouri Mineral Producers and Processors. Missouri Division of Geological Survey and Water Resources, Rolla, Missouri, 1964.

Directory of the mineral industry of Missouri listed by minerals also by counties with a brief report on the status of the Missouri Mineral Industry.

Greene, F. C., and W. B. Howe. "Geologic Section of Pennsylvania Rock Exposed in the Kansas City Area," Missouri Geological Survey and Water Resources, Inf. Circular, No. 8, May 1972.

Booklet includes a graphic section illustrating the stratigraphic sequence exposed in the vicinity of Kansas City, Missouri extending from the base of the Marmaton group to the Tonganoxie sandstone at the base of the Douglas group. The text is essentially an outline of the classification of the beds together with annotations on classification.

Jewett, J. M., A. L. Hornbaker, and J. E. Press. A Guidebook for the Third Forum on the Geology of Industrial Minerals, University of Kansas, Lawrence, Kansas, 1967, 13p.

This booklet describes the physiography geology and industry of the area where Inland Underground Facilities, the largest underground storage area in the world is in operation.

Jewett, J. M. and others. Hydrogeology of the Lower Kansas River Valley: Geological Society of America Annual Meeting, Kansas City, Missouri, guidebook, 1965, pp. 1-45.

Account of an on-site study of the lithology and structure of the rock in which extensive warehousing has been developed in the rooms left from quarrying. Jointing patterns on ceilings and pillars are discussed as well as the bedrock aquifers in the region.

"Mining in Kansas City." Missouri Mineral Industry News, Special Issue, IX, No. 4, Missouri Geological Survey, Rolla, Missouri, 1969.

Same as Dean, Jenkins and Williams article.

"Missouri Geological Survey and Water Resources." Missouri Directory of Mineral Producers and Processors, Info. Circ. No. 20, June 1969.

Sixty-seven page guide to the mineral industry in Missouri.

Parizek, E. J. "Kansas City: Its Geologic Setting," Geotimes, Volume 10, No. 3, October 1965, pp. 9-13.

A summary of the stratigraphy and geomorphology of the Kansas City area. Attention is called to geologic factore which make underground space use feasible in the physical setting of the urban area of Kansas City. Illustrated.

Parizek, Eldon J. and Richard J. Gentile. The Geology of the Kansas City Group at Kansas City, 1965.

A detailed treatment of the rock strata in the Kansas City area including those layers which are pertinent to the development of underground space use. Geologic columns are shown for particular sites and accompanying text describes the character and quality of the rock types.

Stauffer, Truman P., Sr. Guidebook to the Occupance and Use of Underground Space in Greater Kansas City, Geographic Publication No. 1, Department of Geology-Geography, University of Missouri, Kansas City, 1972, 50p.

This guidebook published for the 68th Annual Convention of the Association of American Geographers carries with it many excerpts from the Ph.D. Dissertation done by the author on the same subject. The physiographic, geologic, and geographic features salient to subsurface developed are outlined in the booklet. The booklet is well illustrated.

V. ENGINEERING STUDIES

Roof bolting is a common practice in the redemption of mines where mine and abandon tactics robbed the ceilings. Current use of smooth blasting and planned ceilings have eliminated the need for bolts in most cases.

AMC Coal Division Committee on Roof Action. "Standard Roof Boleting Testing Procedure," Mining Congress Journal, Vol. 45, December 1959, pp. 59-64.

Outline of procedure tentatively accepted by AMC committee on Roof Action. Example given.

Arnould, M. Problems Associated with Underground Cavities in the Paris Region, Association of Engineering Geologist, 1970.

Cites the position of Paris lying over many underground voids of which some are natural due to solution channels in calcareous stone while others are mined out rooms, some rooms were left with pillars occupying 20% of the area while other areas were mined 100% with hand-laid stone pillars left for support.

Aufmuth, Raymond E. A Tentative Geotechnical Engineering Index, presented at the Geological Society of America North-Central Section Meeting at Columbia, Missouri, April 12-13, 1973, p. 16.

Index developed in order to provide a language by which the engineering characteristics of a particular rock may be presented in a brief, concise and relevant manner. Also allows for rapid economical determination of the engineering properties of a material under field considerations. Presents information on the "field shear test."

Bucher, James D. and Shelby K. Willis. Report on Stability of Substrata, October 1970.

This article contains engineering studies on computation of loads of overburden on mine pillars in a specific area in Greater Kansas City. It also treats the possibility of both surface and subsurface development in favorable light.

Burgat, Virgil, Lowell Fowler, Walter Frederickson, Howard O'Connor and Alvin Stallard. 21st Annual Highway Geology Symposium, Field Trip, Geo-Engineering in Northeastern Kansas, April 23, 1970.

Sixty page booklet includes a section on limestone mining in the area, and its secondary use; and a section dealing with a limestone mine cave-in and filling.

Callahan, S. J. and Company. Feasibility of Developing...an Underground Limestone Quarry...and an Industrial Complex Overhead, May 1960.

This article refers to a specific area in Kansas City where mined out rooms have existed for many years. It calculates pillar current support to be 22,000 pounds per square foot with no apparent stress whereas surface buildings would add approximately 500 pounds per square foot. This additional weight was not seen as a deterrent to surface development over the mined area.

Duncan, Donald M. Economics and Development of Shallow Mine Space, Woodward, Clyde, Sherrard and Assoc., Kansas City, Missouri, 1968.

This article covers such topics as the sale of rock, conversion to rental space and real estate development with a general treatment of the geology of the area. Roof performance, delayed roof failures, roof bolting, floor performance, and pillar performance are briefly examined.

Form and Rock Bolt Engineering Catalog No. 727313. Williams Form Engineering Corporation, P. O. Box 7343, Grand Rapids, Michigan, 49510, 1972.

Illustrated general catalog of Williams Rock Bolting Hardware.

Fredericksen, Walter and Richard Gentile. "Guide to Field Trips," *Association of Engineering Geologists*, Annual Meeting, Kansas City, 1972, 109p.

This work, a guidebook, treats many of the geological engineering problems of the Kansas City area especially those where underground space utilization may not be feasible. It also includes a proposed salt mine repository for radio active waste near Salina, Kansas.

Hood, Richard. "Land Drops, Opens in Vibration," *The Kansas City Star*, January 1973, p. 63.

Old abandoned mined out areas collapsed causing damage to nearby homes on the surface. (The new concept of using the space after the rock is removed has so completly altered mining methods that dangers of collapse have been virtually eliminated in areas of recent mining.,

Jacobs, J. D. "Better Specifications for Underground Work," *Civil Engineering*, June 1971, pp. 47-49.

The author cites a need for more explicit details of underground construction.

Jaeger, Charles. *Rock Mechanics and Engineering*, New York, New York: Cambridge University Press, 1972, 417p.

The author treats the subject with an introductory unit proceedings into a study of general rock masses and their properties. Rock mechanics and engineering are covered with an extensive number of case histories.

Langefors, Ulf and B. Kihlstrom. "Smooth Blasting," a chapter in *The Modern Technique of Rock Blasting*, 2nd ed., New York: Wiley, 1967, 405p.

Brief description of the principle and applications, advantages and limitations of smooth blasting. Illustrated.

Lenahan, Tom. *There is a Place for Grouting in Underground Storage Caverns*, paper presented at meeting of the Associate of Engineering Geologists Kansas City, Missouri, October 24-28, 1972.

Thirteen page paper discusses situations which require grouting to make storage caverns functional, as well as grouting materials and equipment recommended for cavern grouting in general. Illustrated.

Moye, D. G. "Rock Mechanics in the Investigation and Construction of T. 1 Underground Power Station, Snowy Mountains, Australia," Engineering Geology Case Histories, No. 3, edited by Parker D. Trask, presented before the Division of Engineering Geology, Geological Society of America, St. Louis, Missouri, November 6, 1958, pp. 13-44.

A detailed account of rock properties, structure, ground water, and stresses. Methods of investigation and measurement are exhibited throughout the work. Illustrations show examples of natural stress, conditions for movement along joints and suggested testing.

"Rock Mechanics and Mine Instruments." Soil Test, Inc., 2205 Lee St., Evanston, Illinois, 60202, 1971, 34p.

Catalog of instruments which have been used extensively in recent years in the development of underground facilities. Illustrated.

Stefanko, R. "New Look at Long-Term Anchorage: Key to Roof Bolt Efficiency," Mining Engineering, 14 (5), 1962, pp. 55-59.

Scientific discussion of new developments in roof bolting, calling for greater application of scientific principles to testing procedures in order to improve bolting efficiency.

Terra Tec Division,Laucks Laboratories, Inc., Overlake Park, Redmond, Washington, 98052, n.d.

Folder containing information on soil, foundation and ground-water flow instrumentation.

Tien, Pei-Lin and Truman C. Waugh. Epsomite and Nexahydrite from an Underground Storage Area, Atchison, Kansas, short paper on research in 1969, ed. by Zeller, 1969.

White efflorescences are formed on limestone pillars in an underground storage and their composition is confirmed by x-ray diffraction. X-ray powder data and pictures of crystal structure are included. The limestone is the Plattsmouth a late Pennsylvanian member.

Valclay Moisture Barrier Systems. American Colloid Company, 5100 Suffield Court, Skokie, Illinois, 60076, 1967. 7p.

Pamphlet describing Valclay waterproofing materials.

Williams Pre-Stressed Rock Bolt Manual. Williams Form Engineering Corp., P. O. Box 7343, Grand Rapids, Michigan, 49510, 1970, 91p.

Illustrated catalog showing many instruments now in use for rock bolting and roof bolting in underground construction. Illustrations and examples.

VI. LEGAL PROBLEMS AND URBAN-QUARRY CONFLICTS

Aaronson, Terri. Problems Underfoot, Environment, Volume 12, No. 9, November 1970, pp. 17-29.

A summary of a U. S. Bureau of Mines report, Environmental Effects of Underground Mining and of Mineral Processing, which has not been published. The report states that 2 million acres of land have subsided as a result of being undermined, and recommends that Congress declare this is a national problem. Although property damage is extensive, especially in urban areas, Pennsylvania is the only state in which the mine owner is legally responsible for damage due to subsidence. The report also notes that Pennsylvania offers subsidence insurance to property owners. Mining has adversely affected 22,000 acres of lakes and 9,000 miles of streams. Solid wastes from mines and air pollution are also problems; coal refuse bank fires are not easily controlled; and underground mine fires are a danger to nearby communities. Ralph Nader suggests that this report has not been published because it would embarrass the coal mining industry.

Blasting: Fire Prevention and Protection. Kansas City, Article III of the Code of General Ordinances, Sections: 14.33; 14.34; 14.36; 14.37; 14.38; 14.39; 14.40.

Text of Kansas City Ordinances giving rules and regulations concerning blasting within the city limits. Permit must be obtained from the city engineer.

Butcher, William. "Rights of Natural Processes," paper presented by W. Butcher, Engineering Foundation Con't. Need for National Policy for the Use of Underground Space, Berwick Academy, South Berwick, Maine, June 24-29, 1973.

Discussion of the legal implications and problems involved in the development of underground space. A methodology and policy governing this new area are viewed as needed now, while conflicts are almost non-existent. Author categorizes the uses of underground space and stresses that allocation to use or non-use is an important aspect to be dealt with since allocation of underground space is usually irreversible except for special cases. We need to plan rationally for this underutilized resource.

"Development Near Lotawana Draws Objections to Mining." Jackson County Sentinel, November 2, 1972.

Citizens protest proposed $500 million limestone quarry golf course development. This development would have been a two tier development with mined rooms below the golf course.

French, R. R., A. W. Stuart, D. H. White. U. S. Department of Interior, Bureau of Mines, Inf. Circ. 8477, Socioeconomic Aspects of Mining in Selected Cities, 1970, 50p. (Urbanization and Surface Mining, Atlanta, Georgia.)

A booklet treating the relationship between mineral resource exploitation and urbanization in the Atlanta, Georgia area. Much demographic, economic and geologic data.

Highsmith, Richard, J. Granville Jensen, and Robert D. Rudd. "Conservation in the United States," Rand McNally Geography Series, 1969, pp. 298-328.

Brief chapter stressing the legal aspects of ownership of mineral resources.

Jacoby, Charles H. Underground Mining, Mine Storage and Other Attendant Uses, paper presented at Conference on Need for National Policy for Use of Underground Space, South Berwick, Maine, 1973.

An 11-page paper. Author predicts secondary use of mined-out caves will become more important than the minerals extracted from it. Discusses uses of this space and makes recommendations for policy toward mining operations.

*Kansas City Times, April 20, 1965.

Part of hill slips into mine on Salisbury Road near Oak Ridge Cemetery in Independence.

*Kansas City, Kansas, n.d.

Cave-in trial where 35 owners of property seek damage.

*Kansas City Times, February 3, 1965.

Dellwig, Antrim, and Hilpman inspect a mine where cave-ins have occurred finding pillars and rooms of appropaite size but variance in overlying stratum above the Argentine minings.

*NOTE: These are typical of areas where "rob and run" tactics were used and ceilings and pillars were exploited. At the time of these mining endeavors no thought was given to a later use of the space which would be left.

*Kansas City Times, January 22, 1965, p. 5.

Ground cracked and popped breaking two houses apart over old quarry in Argentine District.

*Kansas City Star, January 24, 1965.

Cave-in in Kansas City, Kansas at 2035 South 38th Street. Picture of house destroyed by collapse.

*Kansas City Times, January 25, 1965.

No inspections under cave-ins near 37th Street and Steele Road. A suggestion by Antrim, a city engineer, that all underground quarries should be mapped.

*NOTE: These are typical of areas where "rob and run" tactics were used and ceilings and pillars were exploited. At the time of these mining endeavors no thought was given to a later use of the space which would be left.

Knox, Thomas. Underground, Hartford: J. B. Burr & Hyde, 1873, p. 314.

Typical of the historical treatment provided by Knox are the following excerpts: "All over the globe there are caverns where men have lived, sometimes under concealment, sometimes for sanitary reasons, and sometimes because they saved the labor of constructing houses." p. 33.

"The Catacombs of Paris are not used, like the Catacombs of Thebes, Rome, and Naples, as places of original sepulture; for they were once quarries from which the stone employed in building the city was taken.... Their extent is estimated to be about three million square yards; and long before they were cemeteries, they served as refuge and shelter for thieves, incendiaries, assassins, and all the desperate criminals who for many centuries abounded in the city." p. 34.

Kowalcrzk, Zygumunt. Effect of Mining Exploitation on the Ground Surface and Structures in Heavily Industrialized and Populated Areas, The Academy of Mining and Metallurgy, Krakow, Poland, Annual General Meeting Quebec City, Transactions Volume LXIX, pp. 387-393, 1966.

This article presents a theory permitting the determination of expected surface deformations for planned underground exploitations. The relations between surface subsidences and various methods of mining are analyzed and allowable horizontal deformations for protracted objects are reviewed. The research is based on experience with coal mines in Poland; the author recommends the use of safety pillars and discusses many aspects of their use.

Kummer, Richard E. "Geological Considerations in Architecture," Transactions Kansas Academy of Science, Volume 67, No. 2, September 1964, p. 307.

Discussion of the continuing pattern of urban growth in the country and its impact on our geological resources.

Marsden, Sullivan S. and Stanley N. Davis. "Geological Subsidence," Scientific American, June 1967, pp. 93-100.

A recent world-wide geological problem is the sinking of lands (subsidence) resulting from the pumping of oil, gas, and water. Article discusses steps that can be taken to control subsidence and considers the particular case of the Long Beach, California area. Two other examples from Japan are explained, as well as the San Joaquin Valley in California, where an enormous amount of water is pumped from the ground. Finally the author calls for further investigation into measures which can control subsidence.

Office of Research and Development, Appalachian Center, West Virginia University, Morgan Town. Information Series 10, The Mineral Industry and the Environment, Ch. 4, "Pollution of the Landscape," n.d., pp. 18-30.

Little progress has been made in the regulation of landscape pollution through such activities as surface mining and disposal of solid wastes. This is a serious problem but only 20 states regulate surface mining of minerals and few regulate solid waste disposal. Both of these aspects of landscape pollution are discussed and further study of the problem is recommended in order to give needed regulating legislation. In the Chapter, "Impact on the Industry and the Consumer," the report examines the economic impact of pollution legislation, and the growing interest in conservation, calling for detailed studies toward pollution control policy alternatives.

"Quarry Firm Offers to Fix Home." The Kansas City Star, January 14, 1973.

A mining company repaired a house whose foundation was seriously damaged when the earth beneath it collapsed. Most of these problems occur in areas where mining was done years before thought was given to leaving a stable underground void for secondary usage.

Report on the Feasibility of a More Coherent National Policy for the Governance of Underground Space. A report of the study group on the uses of underground space, National Academy of Science, June 1972.

This report cites the competitive claims for subsurface space using San Francisco as an example. It suggests areas where policy objectives are needed and recommends immediate action on the rationale that the future will bring multiplied requests for underground space for visual amenity, to ease social pressures and augment surface space.

Southwestern Reporter. Second Series, Docia Dorman et. al., Respondents vs. Mary Minnich et. al., Defendants, Sup. Ct. of Missouri, June 13, 1960.

Legal problems and tax problems associated with underground space.

Tiffany, Herbert. Modern Law of Real Property, Chicago: Callaghan and Co., n.d., pp. 34, 35, 396.

Discussion of the rights below the surface and significance for underground development.

Trabant, Warren. "Empire of Dead Beneath Streets," Kansas City Star, November 8, 1970.

A historical account of how abandoned quarries became Paris Catacombs as bodies from cemeteries made necessary by urban expansion, were removed there in large quantities.

U. S. Department of the Interior, Bureau of Mines. The Moving Earth, n.d.

A Bureau of Mines film on control of subsidence of mined land.

Wright, Robert R. The Model Airspace Act: Old and New Law for Contemporary Land Use Problems, by Arizona State University, College of Law, 1972.

The author clarifies common law principles which may be extended to apply to ownership of underground space by analogy with above ground airspace.

VII. TUNNELING

As tunneling becomes economically feasible it makes possible the removal of underlying rock without disturbing the already developed surface.

Armstrong, Dr. Ellis L. Underground Space As A Resource, Geological Society of American Symposium on the Underground Environment, Washington, D.C., 1971, p. 15.

Discussion of the future expectations of underground development, in spite of uncertainties of the underground environment. Uses of this resource include conveyance, storage, power plant installations, geology and rock mechanics research, and tunneling research. The author feels new underground techniques will be developed which will greatly enhance the value of underground.

Bleakley, W. B. "Electrofrac - Will it Solve Some of our Toughest Production Problems?" Oil and Gas Journal, Volume 60, No. 7, February 12, 1962, pp. 114-118.

Use of electrical power for in situ carbonization and gasification of hydrocarbons in underground reservoirs may make currently unrecoverable reserves profitable.

Process called Electrofrac and developed by Electrofrac Corporation of Kansas City, Missouri. Process has produced oil from tar, sand and oil shale by electrothermal pyrolysis. It has made stripper wells flow and ignited injection air for gasification.

"Digging The Urban Basement." Mosaic, Volume 4, No. 4, Fall 1973, pp. 10-17.

Article reports on advances in excavation technology which are making underground space more attractive. There are about 20 different ways to excavate rock at the present time, and much development is going on in the field. Also includes a brief report on the subterrene, an experimental rock melter designed for tunneling.

Edwards, John. "Moling for the Millions," British Steel, n.d.

An account of tunneling under London for extensions to one of the most comprehensive underground railway service in the world. Varying soils and geologic strengths are supplemented where needed by cast iron segments.

Electro Fracing: Theory and Practice. Electrofrac Corporation, P. O. Box 8558, Kansas City, Missouri, 64114, pamphlet, n.d.

Small booklet describing a technique to fracture rock by use of electrical energy without explosives. Color, illustrated.

Howard, T. E. "Rapid Excavation," Scientific American, Volume 217, November 1967, pp. 74-85.

Stresses the need to use a systems engineering approach to the design of an efficient rapid excavation system.

Lachel, Dennis. "The Engineering Geologists Role in Hard Rock Tunnel Machine Selection," Geological Factors in Rapid Excavation, Engineering Geology Case History Number 9, edited by Howard Pincus, Geological Society of America, 1973, pp. 5-10.

Lists the advantages of tunneling over drill and blast methods and describes some of the modern tunneling machines with suggestions for exploration when tunnel machine use is planned.

Long Year. Diamond Core Drilling Equipment, 925 Delaware Street, S.E., Minneapolis, Minnesota, 55414, Bulletin 3400, n.d.

Color catalog of Longyear Diamond set products. Illustrated.

Luce, William. What's Ahead in Tunneling Technology, paper presented at the Annuel Meeting of the Geological Society of America, Washington, D.C., 1971, 13p.

A report on many new technological advances and experimental ideas in tunneling. The most outstanding advance during the past decade has been the development of the full face boring machine; other developments include chemical surfactants, water jets, electron beams, flame jets, radiant heaters, and lasers. Liner materials are also discussed.

Saraquu Erich Electofrac Corporation. Rock Breaking by Electrical Energy, P. O. Box 8558, Kansas City, Missouri, 64114, Booklet, September 1972, 34p.

Detailed discussion of the technique of rock breaking by use of electrical energy. Study of several methods now being used. Charts, drawings, and photos.

Stefanko, Robert. "Stabilizing Underground Excavations," from Mineral Industries, Volume 35, No. 3, December 1965, pp. 1-6.

Cites how the science of Rock Mechanics meets some of the problems encountered in underground excavations. Includes a discussion of some research efforts and their problems.

Underground Rock Chambers. American Society of Civil Engineers Symposium, January 13-14, 1971.

Some of the topics covered are:

Underground Rock Structures Challenge the Engineer;
Design of Rock Caverns for Hydraulic Projects;
Rock Tunnels to Control Pollution and Flooding;
Dworshar Dam Underground Crushing Chamber;
Problems with Large Underground Station in Italy;
Northfield Mountain Underground Power Station;
Better Specifications for Underground Work;
"Room and Pillar" Structures in Competent Rock;
Rock Engineering for Underground Caverns.

Wahlstrom, Ernest E. Tunneling in Rock Developments in Geotechnical Engineering, Volume 3, Elsevier Scientific Publishing Co., 1973.

This book is a systematic treatment of such topics as:

Petrography of Unaltered Rocks;
Rock Alteration;
Fracture and Fold Ansiotropy;
Hydrogeology, Temperatures and Gases in Tunnels;
Geological Investigation of Proposed Tunneling Sites;
Methods of Tunneling;
Investigations During Tunneling Operation.

VIII. NEED FOR COMPREHENSIVE PLANNING

These references call attention to the broad spectrum of needs to successfully implement underground development.

Berg, Nils. Aspects on Underground Location of Urban Facilities, Association of Engineering Geologists, 1970.

Use of underground space for storage of urban facilities, power supplies, oil storage, and sewage treatment in Sweden. The underground location of these plants are based more on environmental requirements and landscape shortage than on strict economy. Cites that improvement in tunneling have lowered costs surprisingly while shortage of properly situated space continues to rise. Some examples of compressive stress effect are given.

Boden, Philip K. The Geographical Journal, The Limestone Quarrying Industry of North Derbyshire, Volume 129, Part 1, March 1963, pp. 53-63.

Author traces the development of the limestone industry in Derbyshire, the most important limestone mining county in England. He also describes the industry and its effect on the physical and human landscape. Illustrated.

Brunson, Harbinger. ...The Man and His Company, Volume 11, No. 9, May 1970, pp. 3-9.

An account of the first planned underground factory in the Kansas City area. Brunson quarried and sold the rock with the express purpose of creating a vibration free factory where he could manufacture and set delicate surveying instruments away from the disturbing effect of heavy traffic.

Dean, Thomas J., Gomer Jenkins, James H. Williams. "Underground Mining in the Kansas City Area," Missouri Mineral Industry News, Volume 9, No. 4, Missouri Geological, 1969.

Discussion of limestone mining and the secondary use of safely mined out space. Problems include type and thickness of overburden, groundwater mine design and development, stability, mine life expectancy and mining economics. Author stresses that careful planning during the mining of an underground area is essential if the space is to be re-used. Illustrated.

Edlund, Sten and Gosta Sanstrom. "Stockholm Puts Sewage Plants Underground," Civil Engineering ASCE, Volume 43, No. 9, September 1973, pp. 78-83.

Stockholm has made it a regular practice to put sewage plants underground to save land and eliminate odors. Cost factors and construction technique are discussed, as well as techniques of sewage treatment.

Fellows, L. D. "Geology, Land Use, and Urban Development," Missouri Mineral Industry News, Volume 6, No. 4, April 1966, pp. 38-49.

Geology has not played as important a part in urban development and land use as it should. Population growth will make geology more essential to these activities. Geological studies help insure the most intelligent, beneficial use of land, prevent the waste of mineral deposits and water resources, help in building sound structures, and improve living conditions.

Fertig, Wendell W. "Mined Land Conservation," The Mines Magazine, October 1966, pp. 5-8.

Author asserts the need and practically of reclaiming mined lands, noting some actions taken by states in this direction. Phosphate strip mining is discussed; as well as open pit mining. Conservation and the public interest must be considered in the use of mined land. The Mined-Land Conservation Conference was formed in 1963. It is to encourage proper reclamation. Active members are surface mine operators and their associates.

Gottman, Jean. "Why the Skyscraper?" Geographical Review, Volume LVI, April 1966, pp. 109-212.

Article traces the development of the skyscraper, notes different levels of use of skyscrapers in different countries, and investigates the philosophy behind their use. Author believes the skyscraper expresses the need to accumulate floor space for offices and related activities, providing concentration for many interconnected activities; it is also an expression of the social evolution of society, the increase in "white collar workers." Gottman also believes skyscrapers are evidence of a competitive society and a free economy. Skyscrapers are also an expression of the art of living. The author of this bibliography sees the development of underground space as carrying the attributes of the skyscraper in an inverse direction.

Gray, Russell T. Where Your Industrial Markets Lie, 155 North Wacker Drive, Chicago, Illinois, n.d.

A smart illustrated pamphlet explaining how to properly plan and execute industrial advertising through market research.

Harris, Chauncy. "The Market as a Factor in the Localization of Industry in the United States," from Annals of the Association of American Geographers, Volume XLIV, No. 4, December 1954, pp. 315-348.

A study of the importance of the market, location of markets, market potential and area distribution. Included are discussions of regional markets with a concentration on agriculture, mining and manufacturing on a regional basis.

Hart, John. "A Map of Mining Employment in the United States, in 1960," from the Minnesota Geographer, Saint Cloud University, 1960, pp. 1-8.

Discusses various measures of the importance of mining employment in the rural U.S., with an "index of mining employment" and maps of U.S. depicting the regional values of this index. Author believes this indexing method can also be applied to other distributions.

Harza, Richard. National Commitment to Better Urban Life Assures a Rapid Growth in Underground Construction, The Geological Society of America Symposium, Washington, D.C., November 3, 1971, 8p.

A survey of the history and future of urban underground construction development will become more important as land becomes less abundant and more costly.

Hayes, William and Jerry Vineyard. "Environmental Geology in Towne and Country," Educational Series No. 2, Missouri Geological Survey and Water Resources, August 1969.

Forty-two page booklet explaining environmental geology, its importance, use, application and impact. Includes illustrations and bibliography.

Hilpman, Paul. "The Governor's Conference on Environmental Geology," Urban Growth and Environmental Geology, Colorado Geological Survey, Special Publication No. 1, Denver, Colorado, April 30-May 1-2, 1969, pp. 16-19.

The discussion of land-use planning to eliminate unnecessary waste of resources. Discussed are examples of land-fill projects, underground warehouse space/use in the Kansas City area and multiple land use practices. Geologists should make geologic data available to planners but also continue classical geological studies.

Hilpman, Paul L., and Gary F. Stewart. "Geology and Concern for the Environment," Highway Research Record, No. 271, 1969, pp. 38-47.

Explains how geologists and geological techniques can contribute to environmental planning. Discuss need for expanded communication between geologists and laymen. Author estimates 1,000 environmental geologists are needed in urban areas of U.S. and this will increase.

Hilpman, P. L., G. F. Stewart, and others. A Pilot Study of Land-Use Planning and Environmental Geology, U. S. Department of HUD and Kansas Department of Economic Development, 701 Project No. Kansas, 1968, p. 43, 63p.

This study identifies the Plattsmouth Limestone member as an important rock which is marketable as crushed stone. This same strata in nearby Atchison, Kansas has been mined by room and pillar method and the rooms are currently in use as underground storage by the U.S. for military purposes. This report, however, does not suggest similar uses for the Plattsmouth Limestone in this study area.

Hoch, Irving. Economic Trends and Demand for the Development of Underground Space, Engineering Foundation Conference, South Berwick, Maine, (Resources for the Future, Inc., 1755 Massachusetts Avenue, N.W., Washington, D.C., 20036), June 1973, 66p.

A discussion of the effects of price changes, concern with the environment and urban population distributions on underground developments. Charts and graphs. Author predicts pronounced increase in demand for underground space.

"Invisible Architecture in the Paris Underground." Fortune, Vol. 73, January 1966, p. 176.

An example of the construction of an underground office building due to limitations on available surface area. UNESCO's 3-story underground building is seen from the streets around it as only grassy lawns and shrubbery. Natural lighting is also used.

Iwatsuka, Ryozo. "Underground Sewage Treatment Plant in Tokyo," Civil Engineering, Volume 38, No. 11, November 1968, pp. 49-52.

Tokyo was one of the last large cities in the developed countries to initiate a modern sewer system. The underground treatment plant in Ochiai is part of this system and has functioned very successfully in its first 4 years, even becoming one of Tokyo's interesting sightseeing sports. 30,000 people have enjoyed the park on the top of its aeration tank.

Jansson, Birger. The Urban Development and the Demand on the Underground During the Year 2000, paper presented at the Annual Meeting of the Geological Society of America, Washington, D.C., 1971, 10p.

Author discusses problems and future possibilities of urban underground development, with examples from the Stockholm, Sweden subway construction. Author describes 4 reasons for underground development: protection, communication, space and economy. External factors affecting these motives are population density, economic standards, and social standards. Other factors are environmental demands, safety and technical standards, geographical demands, laws and regulations. Author predicts increase in underground developments. Illustrated.

Kansas City, Kansas Planning Department. Land Use Report for Kansas City, Kansas, November 1968, 30 pages with maps.

The land use plan, based on an analysis of the various factors of existing use, topography, street patterns, etc., seeks to establish a rational relationship between the uses which will accomplish more convenience and orderly growth as well as meeting the present and future needs of the city.

Kansas City Real Estate Market Letter. Kansas City Cave Space, (1016 Baltimore, Kansas City, Missouri, 64105), Volume 21, No. 2, April-June 1968.

Report reviews the underground mine space available today in the Kansas City area and its potential for warehousing and manufacturing. Reviews advantages such as low initial cost, etc.

Koelzer, Victor A., et. al. Chicagoland Deep Tunnel Project, paper presented at Mtg. Inters., O.L. Compact Comm. Miami, December 5, 1968, 31p.

Report on the Chicagoland Deep Tunnel Project, which was designed to provide flood and pollution control. Also notes that the dolomite under the Chicago area in well-smited for underground development and lists potential uses.

LaNier, Royce. "Geotecture," Subterranean Accommodation and the Architectural Potential of Earthworks, Department of Architecture Notre Dame University, Notre Dame, Indiana, circa 1972.

This work treats the need for a new set of architectural forms which utilize natural elements of the semi-subsurface and subsurface in various uses including human habitation.

Lewthwaite, Gordon R. "A Plea for Storage Geography," The Professional Geographer, Volume XXI, No. 1, 1969, pp. 1-4.

Author cites the need for a "storage geography," illustrating his arguments with examples from early New Zealand Maori food storage practices and from other early cultures as well. In spite of the modern use of canning, refrigeration and dehydration, storage is still a problem and we could learn much from studying different food storage patterns.

Loofbourow, R. L. "How to Cut Underground Construction Cost," Civil Engineering, Volume 42, No. 6, June 1972, pp. 85-87. (American Society of Civil Engineers, ASCE, New York).

Cities looking underground for space to grow. In areas of high-land cost underground transportation tunnels, shops, warehouses and parking may be economically feasible. Factors that make low cost mining possible are, physical state of rock and control of fracturing by method of working, uniformity of physical character of work facilities, planning and mechanization, and no serious water inflows.

The study indicates many cities near which there are large masses of rock likely to be sound and tight at depths which are minable and suited to one or more of the space uses suggested.

Mattes, L.R.D. and W. Stewart Matthew. "Prepare to go 100% Underground," American City, October 1967, p. 62.

Article predicts almost completely underground utility distribution systems for the U.S. in the near future. The cost of underground utility delivery has decreased greatly and there is much public demand for this due to aesthetic and safety factors. Also underground construction technology is more developed. The demand for converting present utility distribution systems will also grow but at a slower pace than new installation of underground systems.

Missimer, H. C. "Avoiding Utility Interference Underground," Civil Engineering, New York, September 1965, pp. 36-38.

Discusses the problems arising from congestion of underground utilities and the solutions which have been worked out in Philadelphia. A great deal of combined efforts on the parts of the government, utilities and construction firms are needed.

Neff, Thom L., Project Engineer, E. D. Appolonis Consulting Engineers, Inc. An Approach to Underground Construction, presented at 15th Annual Meeting of the Association of Engineering Geologists, Kansas City, Missouri, October 24-27, 1972.

Current discussion of immense possibilities of underground construction and problems with an outlook for the future. The Bureau of Reclamation has started a $5 million field research program to develop underground construction technology. New contractual arrangements would also be helpful. The paper offers 2 possible contract models, adversary and incentive, and discusses the advantages, and the controls required with the use of the incentive approach being recommended. The philosophy of current civil engineering approaches are discussed.

Panero, Robert B. Mines and Other Concepts, Protective Construction in a Nuclear Age, New York: The Macmillan Company, Volume 1, 1961, from the Second Protective Construction Symposium, The Rand Corporation, 1959.

Discussion of the concept and availability of mine sites as important sources of protection of man or agencies. Author discusses mining operations and the types of space resulting, the different specifications of military and civilian use of this space, and uses of underground space. Engineering design problems are examined. Illustrated.

Parizek, Eldon J., to Chancellor James C. Olson. Memorandum, October 29, 1971.

Statements and supportive materials concerning subsurface development proposing establishment of a National Institute for the Development of Underground Space at the University of Missouri-Kansas City. The proposal is predicated on the location of the UMKC campus in the Kansas City area where the geologic setting has allowed the most extensive underground development in the world to occur.

Parizek, E. J., Wallace B. Howe and James H. Williams. "Geology of Independence Quadrangle Jackson County, Missouri," Geological Survey and Water Resources, Series No. 1, May 1968.

Geologic mapping with brief description of exposed strata of Pennsylvanian age and unconsolidated deposits of the Quaternary Age. Discussion as well as brief description of their economic geology. Engineering studies show that sites suitable for sewage lagoons and other impoundments are restricted to certain parts of the area, and that in some areas swelling clays and shales may cause damage to poorly-designed structures.

Pecora, William T. "New Horizons in Natural Resource Management," The Professional Geographer, Volume XXI, No. 2, March n.d., pp. 73-78.

Originally an address to the 64th Annual Meeting of the American Association of Geographers, this paper asserts the need for geography and geology to draw closer together. The article discusses new areas which the U.S. Geological Survey will deal with in the coming decade: the search for resources in the ocean, the utilization of space science techniques, creation of national water resource systems, engineering planning alternatives, land use patterns in urban growth, new kinds of maps, and a national atlas of the U.S.

Schlicker, Herbert G. Nonmetallic Mining in an Urban Environment, State of Oregon, Department of Geology and Mineral Industries, n.d.

Proposes that plans to re-use mined land must be included in long-range planning by local governments.

Second International Symposium on Underground Waste Management and Artificial Recharge. New Orleans, Louisiana, American Association of Petroleum Geologists, 2 Volumes, September 26-29, 1973.

This is a collection of 43 complete papers and 3 abstracts on underground waste management.

Shadmon, Asher. Quarry Site Surveys in Relation to Country Planning, from XXIII International Geological Congress, Volume 12, 1968, pp. 125-132.

A study of the need for considering quarry sites in country planning. Included are esthetic considerations, disturbance factors, topographic and physical factors, of quarry siting.

Sheridan, M. J. Urbanization and its Impact on the Mineral Aggregate Industry in the Denver, Colorado, Area, IC 8320 U. S. Department of Interior, Bureau of Mines, Washington, D.C., 1967, 53p.

This article cites the need for long range planning to resolve the conflict between mining of raw materials and encroachment of urban expansion. It treats all rock and mineral production without specific regard to underground mining or secondary use.

Smith, D. M. "A Theoretical Framework for Geographical Studies of Industrial Location," from Economic Geography, Volume 42, No. 2, April 1966, pp. 95-113.

Author stresses need for theory in industrial geography, discusses several aspects in the selection of industrial locations. Graphs and illustrations included.

Stollman, Israel. The Uses and Principles of Planning, "A Place to Live: Yearbook of Agriculture U.S.D.A.," 1963, pp. 367-376.

Discusses regional planning its purposes and principles, and the role of government. Author stresses the need for comprehensiveness and professionalism, and notes that the distinction between urban and rural planning has disappeared. Stresses the need for interdisciplinary action in solving problems.

Swiger, W. F. Can We Place Nuclear Power Plants Underground, paper presented at meeting of Geological Society of America, November 3, 1971, Washington, D.C., 19p.

Author believes the underground nuclear power plant is practicable and may offer advantages under certain conditions. A study of two approaches, totally underground and partially underground. Underground arrangement requires competant rock while the partially exposed approach is adaptable to various geologic conditions. Advantages of underground location are many but primarily they have public acceptance because they can be designed against earthquake hazard and external hazards such as tornados, landslides, and aircraft impact. Economical costs of underground construction are not clear. Total cost involves more than digging but also needs access tunnels, portals, etc. Author, therefore, does not think they would be economically competitive with above ground installation.

"Tokyo Fights the Garbage Battle." Kansas City Times, December 26, 1973, p. 7F.

Article discusses the problems facing Tokyo in disposing of its garbage and mentions a planned system of underground pipes that would carry garbage by compressed air from small scattered underground stations to large incinerators.

Use of Underground Space to Achieve National Goals. Report conducted by the Underground Construction Research Council of ASCE in Cooperation with AIME.

The report devotes attention to:

I. Relating Underground Construction to National Goals
II. Evaluation of Life-Support Systems
III. Technical Feasibility
IV. Alternative Program Requirements
V. Obstacles to Implementation
VI. Resource Requirements
Bibliography

Utudjian, Edouard. Urbanisme Souterrain, Presses Universitaires De France, Paris, 1964.

A short history of the use of caves in Palestine and during the middle ages in France. The use of the underground for tunnels, defense as in the Maginot line, mining, and burial are cited. He then treats the potential of urban expansion by use of the subsurface showing need for planning, problems to be solved, and the resultant multi-tiered city. (in French).

Vineyard, Jerry D. "Natural Resources," Recreational Geology and Planning, Annual Spring Conference of Missouri Planning Association, Rolla, Missouri, March 15-16, 1968.

Geologists are assuming a more important role in planning today. An example of the benefits of this is the use of mined-out limestone areas for office or industrial space, or the secondary use of open pit quarries. The planner should consider sequential use of mineral lands, which includes areas which have been strip mined. Geologists can help the planner recognize "hidden" natural resources; aid in highway construction; and point out geologic features that can be focal points of recreational areas. Article gives many examples of geologist-planner relationships in Missouri.

Wayne, William J. Urban Geology--A Need and a Challenge, Proceedings of the Indiana Academy of Science for 1968, Volume 78, 1969, pp. 49-68.

This work while not specifically treating underground space development does treat the need for understanding the nature of the geologic setting in urban areas. It is a well written paper in layman's language and would serve as an introduction to understanding the interface between urban uses and the subsurface of the city.

Wheeler, Henry and William Eckard. Underground Storage of Natural Gas in Coal Mining Areas, from Bureau of Mines Information Circular No. 7654, December 1952, 10p.

Excellent survey and discussion of underground storage of natural gas. How to choose locations and develop a gas storage field. Included are tables, charts, and illustrations. Authors discuss relationship of coal industry and natural gas industry.

Wood, A. M. Muir and J. H. Bird, I. Thompson, K. D. Wickenden, H. Grimond, M. R. Bonavia. "The Channel Tunnel," Geographical Journal, Volume 139, Part 2, June 1973, pp. 258-279.

The spatial effects on population and industrial complexes by the construction of an underground channel between France and Britain are examined.

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